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Frequency and Chronological Distribution of Linear Enamel Hypoplasia in a North American Colonial Skeletal Sample

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ABSTRACT A skeletal sample of 44 individuals born and raised in early 18th century frontier settlements of Northeastern United States is examined for the frequency and chronological distribution of linear enamel hypoplasia (LEH) on the maxillary and mandibular incisors and canines. The prevalence of LEH ranged from 31% on the I^2 to 66% on the mandibular C and the mean number of defects ranged from .59 on the I^2 to 1.08 on the mandibular C. These frequencies were generally lower than those reported for two later samples; the Monroe County Poorhouse sample and the Hammon-Todd sample. Individuals in these latter two samples were derived from the lowest socioeconomic stratum of their respective populations. Frequency differences are explained within the context of the changing availability of resources that resulted from the rise of industrialization, urbanization, and wage labor which took place during the 18th and 19th centuries.

The frequency of LEH was low prior to 1.5 years of age and may result from attrition and/or decreased susceptibility in the relevant area of the crown or from low morbidity or high mortality. Peak frequencies are observed in all age categories ranging from 2.5 to 3.0 years up to 4.0 to 4.5 years and are too late to result from weaning. Instead, they may reflect the susceptibility of nonimmune children to diseases that were common in colonial North America. As the majority of these diseases were not fatal, most victims who survived may have had one or more LEHs as visible proof of their earlier encounter(s).

Linear enamel hypoplasia (LEH) is a deficiency resulting from cessation or interruption of deposition of enamel rods during the secretory phase of enamel development. On the mature tooth LEH is manifest as circumferential lines, bands, and less commonly, pits of decreased enamel thickness (Goodman and Rose, 1990). LEH has no specific etiology, but results from a wide variety of systemic disturbances severe enough to disrupt amelogenesis (Kreshover, 1960). Because enamel formation proceeds sequentially from the tip of the crown to the base, the distribution of an enamel defect indicates the age at which the stress occurred (Cohen and Diner, 1970).

A plethora of studies have reported analyses of LEH in prehistoric samples (e.g., Blakey and Armelagos, 1985; Cook and Buikstra, 1979; Goodman et al., 1980; Sciulli, 1978; Whittington, 1992) and the rationale and methods for this research are now well established (see Goodman and Capasso, 1992). To date very few studies involving his-

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toric samples, which provide the rare opportunity to compare LEH observations with information available from the comparable time period, have been published (Blakey et al., 1994; Hall and Browman, 1992; Lanphear, 1990; Moggi-Cecchi et al., 1994). Specifically, the author knows of no published LEH analysis of a skeletal sample from the North American colonial era. As such, research in this area would be fruitful. The research sample is composed largely of young males, born and raised in early 18th century frontier settlements of New England and eastern New York State. It is believed that they represent colonial-born individuals (Cybulski, 1991) and may be the offspring of the first European immigrants to this area. LEH data from the sample were interpreted within the context of historical data from the relevant geographical location and time frame.

MATERIALS AND METHODS

Skeletal sample

The skeletons, 52 of which have been excavated to date, were discovered in August 1986 near the fortification wall of Québec City during a Parks Canada project to repair the wall. There are no historical records for a cemetery in the area. However, Québec historians recovered documentation suggesting that the bodies belong to colonial-born Protestant prisoners held by the French in 1746–1747 following an outbreak of war between France and England. "They were captured during staccato raids to the east and south of Québec by the French and their Indian allies, aimed at keeping the enemy disorganized and unable to launch a large-scale campaign" (Cybulski, 1991:64).

According to the dairy of a captive who survived and was eventually released (Pote, 1976), most of the prisoners were from New England and eastern New York State and included individuals of Dutch, Irish, German, and Norwegian descent. A small number may have been Scottish or English sailors.

Forty-four individuals were included in the sample, but, depending on completeness and condition of the teeth, sample size for each tooth type ranged from 31 to 38 teeth. Age and sex distribution of the sample is given in Table 1.

TABLE 1. Estimated age, sex, and year of birth

Burial	Sex	Age	Year of birth[1]
19G35C2	M	20–24	1722–1726
19G35C3	M	35–44	1702–1711
19G35C4	M	20–24	1722–1726
19G35D1	M	18–22	1724–1728
19G35H1	M	20–24	1722–1726
19G35H3	M	25–34	1712–1721
19G35J1	M	22–28	1718–1724
19G35J3	M	45–54	1692–1701
19G35K1	M	25–34	1712–1721
19G35K3	M	16–18	1728–1730
19G35K4	M	40–49	1697–1706
19G35K6	M	25–34	1712–1721
19G35K7	M	14–16	1730–1732
19G35K8	M	25–29	1717–1721
19G35K9	M	20–24	1722–1726
19G35K10	M	28–34	1712–1718
19G35K11	M	22–28	1718–1724
19G35K12	M	65–74	1672–1681
19G35K13	M	17–20	1726–1729
19G35L1	M	18–21	1725–1728
19G35L2	F	18–21	1725–1728
19G37E3	M	20–24	1722–1726
19G37E4	M	28–34	1712–1718
19G37E5	M	40–49	1697–1706
19G37E6	M	35–44	1702–1711
19G37F2	M	55–64	1682–1691
19G37F3	M	60–69	1677–1686
19G37F4	M	20–24	1722–1726
19G37F5	F	28–34	1712–1718
19G37H1	F	28–34	1712–1718
19G37K1	M	17–20	1726–1729
19G37K2	?	8–11	1735–1738
19G37L1	M	18–21	1721–1728
19G37M1	M	25–29	1717–1721
19G37M2	M	18–21	1725–1728
19G37M3	M	18–22	1724–1728
19G37M4	M	25–34	1712–1721
19G37N1	M	18–21	1725–1728
19G41C1	M	28–34	1712–1718
19G41C2	M	28–34	1712–1718
19G41C3	M	22–28	1718–1724
19G41D1	M	45–54	1692–1701
19G41D2	M	18–21	1721–1728
39Q6B24Q	M	30–39	1707–1716

[1]Estimated age (from Cybulski, 1991) was subtracted from the year of death, 1746, to arrive at year of birth.

Health status

The Pote (1976) journal was kept from May 17, 1745, the day of Pote's capture by French and Indians, to August 9, 1747, the day all surviving prisoners were released from the prison. During his incarceration, Pote noted the arrival of over 300 prisoners, 107 identified by first and last name. Information such as age, sex, ethnic origin, location of capture, and data of capture or imprisonment was also included. Of the 69

deaths recorded by Pote, the place of origin of 55 (80%) was specified as New England, New York, Pennsylvania, or Connecticut, and of 6 (9%) as Europe. For the remaining 8 (11%) the origin was not specified. For the present study it was assumed that the 44 skeletons were derived in proportion to these figures. Research focused on the early 1700s when the majority of individuals were children (see Table 1). Historical, medical, and demographic sources were consulted to provide information pertaining to biological stress experienced by this particular population. The information derived was used as a means of interpreting that inferred from analysis of the prevalence and chronological distribution of LEH observed in the skeletal sample.

Methods

LEH observations were recorded from the left mandibular and maxillary incisors and canines. The right antimere was used when the left tooth was not observable. According to the rationale presented by others (El-Najjar et al., 1978; Goodman et al., 1980), because of timed differentials in growth, a tooth-by-tooth developmental chronology for these six teeth spans the period from birth to 6.5 years of age.

LEH was defined as a continuous horizontal groove or depression, or as a horizontal line of pits, across the labial surface of the tooth. All observations were made without recourse to hand lens or stereoscope. Defects associated with a broad depression were easily observed, but less prominent hypoplasias were detected by manipulating the tooth in natural light (to reduce reflectance off of the shiny enamel surface).

Each tooth was rated for presence or absence of LEH by type present; linear pits and/or linear grooves. The total number of hypoplasias was recorded by tooth type based on the number observed on the labial surface of the crown. When the observation could not be made, the category "indeterminate" was employed.

The height from the midline of the base of the crown to each hypoplastic defect was recorded to the nearest tenth of a millimeter with a needle-pointed dial caliper. Each measurement was converted into age of occurrence of the defect. The developmental chronology used (Patterson, 1984) followed that of most current research: based on Swardstedt's (1966) modification of earlier standards (Massler et al., 1941). Following Goodman and Rose (1990), the assumption of constant velocity in the rate of tooth formation was adopted. Age of defect formation was estimated by assigning each defect to 0.5 year intervals, depending on location on the tooth surface. The use of developmental stages, as opposed to absolute age estimates, reduces the number of incorrect assignments due to individual variability within a 6 month range.

Ideally, timing of developmental defects should be based on the crown height of each individual tooth in question (Hodges and Wilkinson, 1990) but, in this sample, slight to moderate attrition affected 58% of the teeth. When attrition was severe (i.e., one third or more of the crown was obliterated) the tooth was eliminated from the sample. As a result, average crown heights, by tooth type, were determined for the sample based on measurements of all unworn teeth to the nearest 0.01 mm. With the exception of I_2, the average height of each tooth was larger than that reported by Swardstedt (1966) and Goodman et al. (1980). Do larger teeth develop over a longer period of time, involving earlier onset and/or later completion of enamel formation; or, alternatively, do larger teeth simply develop more rapidly? To date, the relationship between crown height and duration of enamel development is unkown. Therefore, the assumption of rapid development was adopted as it has been in the majority of studies to date.

RESULTS

Prevalence

Of 44 individuals, 35 (79.5%) had one or more cases of LEH. Only one defect was represented by a linear band of pits, all others were represented by a linear depression across the labial surface of the crown.

The frequency of LEH in the maxillary teeth ranged from 31% for the I^2 to 50% for the C (Table 2). The frequency of LEH in the manidibular teeth ranged from 43% for the I_1 to 66% for the I_2 (Table 2). The mean num-

TABLE 2. Prevalence and mean number of enamel hypoplasias by tooth type and dentition

	Maxilla			Mandible		
	Canine	Lateral incisor	Central incisor	Canine	Lateral incisor	Central incisor
One or more	16/32 (50%)	11/34 (31%)	14/31 (45%)	23/38 (61%)	25/38 (66%)	15/35 (43%)
Mean number	0.78	0.59	0.74	1.08	0.82	0.60

ber of LEH events per tooth type ranged from .59 on I^2 to 1.08 observed on the mandibular C (Table 2).

The prevalence of LEH in the present sample was compared to published data of LEH prevalences in two skeletal samples of American-living whites (the Hammon-Todd collection reported by El-Najjar et al., 1978 and the Monroe County Poorhouse collection reported by Lanphear, 1990). The comparison was thought justified because similar methololgies were used in all three studies. Individuals in all three samples represent European immigrants and the descendants of European immigrants who lived in Northeastern United States from the early 18th to the early 20th century. Observed differences in prevalence of LEH, and thus health status, will be explored within the context of the dramatic social and economic changes that took place in this geographic region during the 200 years following the beginning of the 18th century. The Hammon-Todd collection represents individuals born in the greater Cleveland area between 1855 and 1913 (El-Najjar et al., 1978). The Monroe County Poorhouse sample is composed of inmates who died at the Poorhouse, located just outside of the city of Rochester, New York, between 1826 and 1863 (Lanphear, 1990). These individuals are estimated to have been born in the late 18th to middle 19th centuries. Both samples consist of individuals from the lowest socioeconomic stratum of their respective populations. In summary, the colonial American sample represents individuals born in the early 18th century, the Monroe County Poorhouse sample represents individuals born in the late 18th and first half of the 19th century, and the Hammon-Todd sample represents individuals born in the second half of the 19th century and early 20th century.

For the maxillary dentition, prevalence of LEH in the central incisors was 84.9% in the Hammon-Todd sample (El-Najjar et al., 1978), 63.6%[1] in the Monroe County Poorhouse sample, and 45.0% in the North American colonial sample. Values for I^2 and C were 74.0% and 78.6% in the Hammon-Todd sample and 31.0% and 50.0% in the colonial sample (Table 3). For the mandibular dentition, LEH in the canines was 86.7% in the Hammon-Todd sample, 45.9% in the Monroe County Poorhouse sample, and 61% in the North American colonial sample. Values for I_1 and I_2 were calculated as 91.4% and 83.0% in the Hammon-Todd sample, and 43% and 66% in the colonial sample (Table 3).

The prevalence of LEH in the Hammon-Todd sample was consistently higher among all tooth types than that observed in the colonial North American sample, whereas in the Monroe County Poorhouse sample the prevalence of enamel hypoplasia among the maxillary central incisors was higher than that observed in the maxillary incisors of the colonial sample, but lower than that observed in the maxillary incisors of the Hammon-Todd sample. The prevalence of LEH observed among the mandibular canines in the Hammon-Todd sample was higher than that observed among the mandibular canines in the Monroe County Poorhouse sample which was in turn lower than that observed in the colonial North American sample. Thus, the highest prevalence was observed in the Hammon-Todd sample, the lowest in the colonial American sample, with the exception of the mandibular canine.

Chronological distribution

Figure 1 illustrates the frequency distribution by age of LEH among the three maxil-

[1]Lanphear (1990) reported 143.1 enamel hypoplasias among 225 left and right maxillary central incisors and 143.3 enamel hypoplasias among 312 left and right mandibular canines. I calculated the prevalence to be 63.6% for the former and 45.6% for the latter.

TABLE 3. Comparison of prevalence of enamel hypoplasia among three skeletal samples by tooth type and dentition

	Maxilla			Mandible		
	Canine (%)	Lateral incisor (%)	Central incisor (%)	Canine (%)	Lateral incisor (%)	Central incisor (%)
North American colonial	50.0	31.0	45.0	61.0	66.0	43.0
Monroe County Poorhouse	N/A	N/A	63.6	45.9	N/A	N/A
Hammon-Todd	78.6	74.0	84.9	86.7	83.0	91.4

lary teeth in the colonial North American sample. In the I^1 the peak frequency of events occurred at 2.5–3.5 years of age. In the I^2 the peak frequency of defects was observed at 3.0–4.0 years with a second peak at 2.0–2.5 years of age. The distribution for the maxillary canine revealed two peaks, at 3.5–4.0 years and a second, slightly more pronounced, at 4.0–4.5 years.

Figure 2 illustrates the frequency distribution by age of LEH among the three mandibular teeth in the colonial North American sample. In both the central and lateral incisor the peak frequency of events occurred at 2.5–3.0 years of age while the 1.5–2.5 age categories also exhibited relatively high frequencies of LEH. (In fact all LEHs observed in the central incisor occurred between 1.5–3.0 years of age.) For the canines, the peak frequency of defects occurred at 4.5–5.0 years of age while age categories 3.0–4.5 also exhibit relatively high frequencies of LEH.

In summary, based on all six tooth types, the majority of hypoplastic defects occurred between 1.5–5.0 years of age from the possible age range of birth to 6.5 years of age.

DISCUSSION

Prevalence

The highest prevalence of LEH was observed in the Hammon-Todd collection. The colonial North American sample had the lowest prevalence, except in the mandibular canine, in which the prevalence of LEH was lowest in the Monroe County Poorhouse sample. When the mean number of LEHs per tooth type were compared between the Monroe County Poorhouse sample and the colonial sample, the former had higher counts from both I^2 and C. These differences can be explained within the context of the changing availability of resources that resulted from the rise of industrialization, urbanization, and wage labor which took place during the 18th and 19th centuries.

In the late 17th century and first half of the 18th century, when the majority of individuals in the colonial North American sample were born, differentiation of socioeconomic status had not yet developed in the frontier settlements of New England and New York and the vast majority of colonists were agricultural land owners (Main, 1965). In fact, an abundance of land prevented overcrowding—migration to the frontier was the primary means of relieving population pressure (McCusker and Menard, 1985). Because population density was low, the incidence of infectious disease was also low (Norton, 1971). High standards of living in the New World were immediately felt by new immigrants (Shryock, 1979) with superior levels of nutrition (Sokoloff and Villaflor, 1982), impressive life expectancies (Wells, 1975), low mortality (Meindl and Swedlund, 1977), and high fertility (Osterud and Fulton, 1976). Severe outbreaks of disease, combined with the occasional food shortage, were never more than temporary setbacks to social and economic development (Duffy, 1953).

In the late 18th century and the first half on the 19th century, when the majority of individuals in the Monroe County Poorhouse sample were born, the transition from an agricultural to an industrial-based society was beginning to take place in both North America and Europe. The "preindustrial era" was characterized by extremely rapid population growth, mainly as a result of European immigration, which reached record highs after 1820 (Mohl, 1972). Most immigrants settled in the cities and were joined by rural migrants whose agricultural endeavors had failed. At the same time, the middle and upper-class were moving from

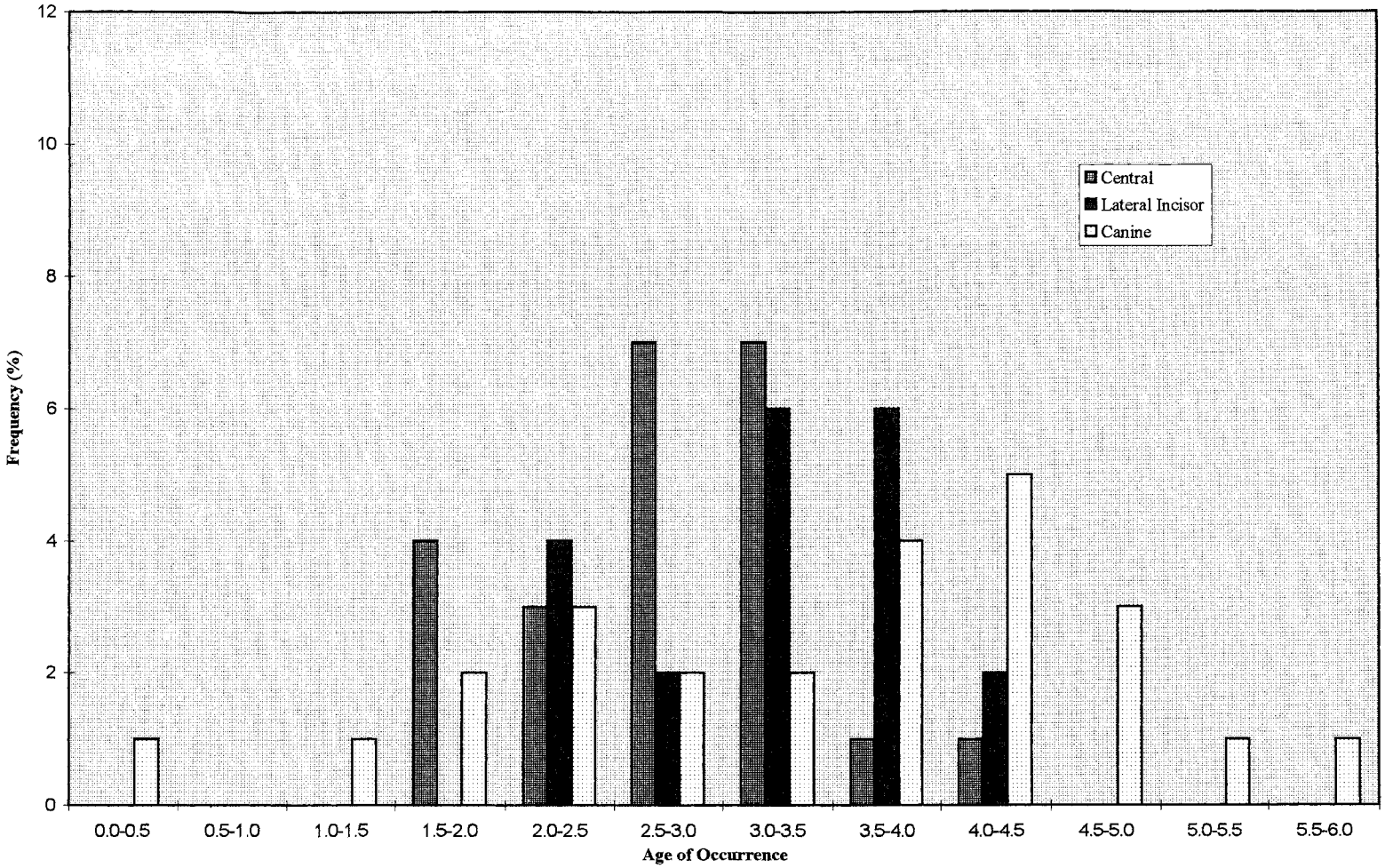

Fig. 1. Frequency distribution by age of enamel hypoplasias among the maxillary dentition in the colonial North American sample.

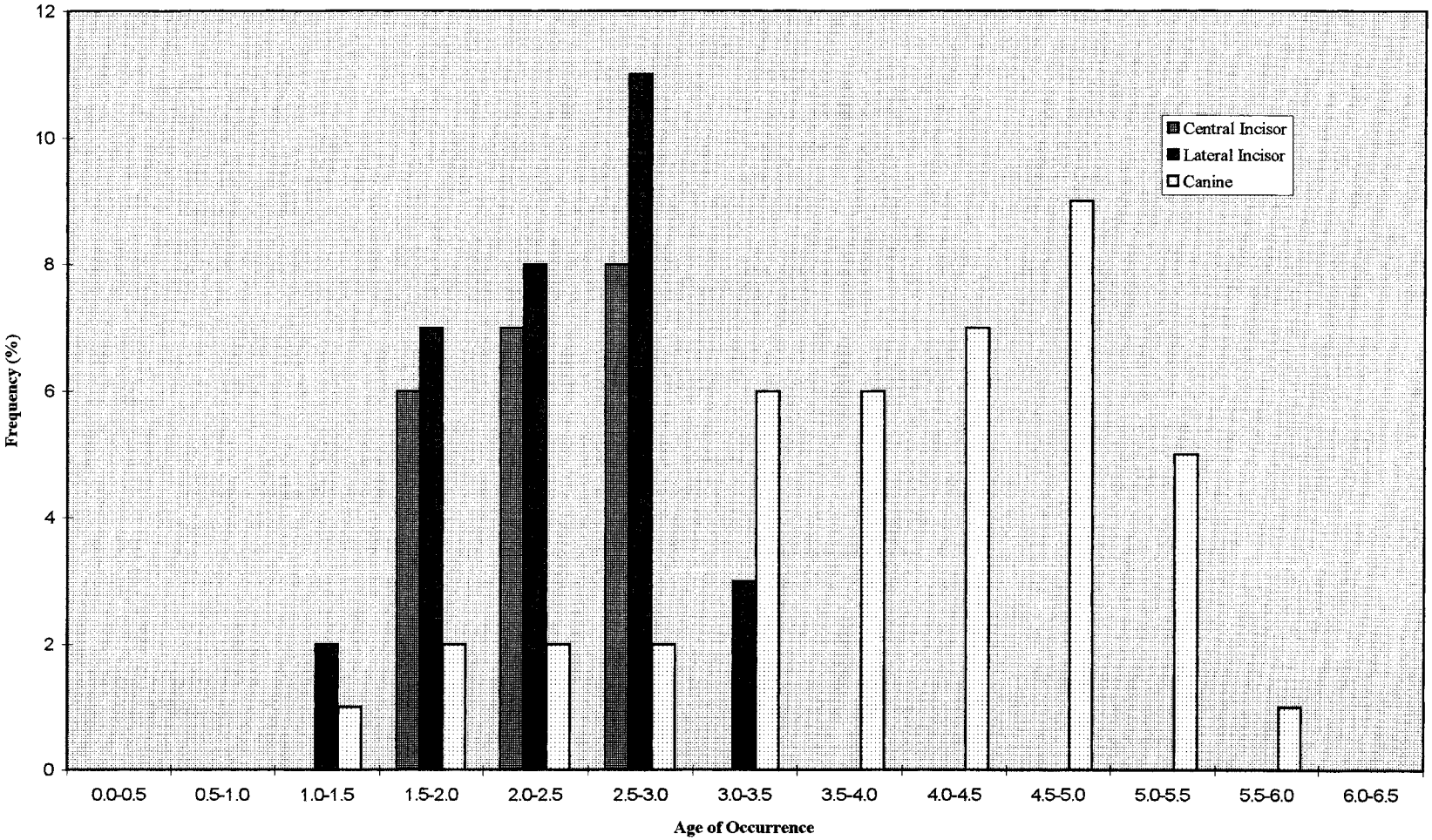

Fig. 2. Frequency distribution by age of enamel hypoplasias among the mandibular dentition in the colonial North American sample.

their urban homes to new homes in the suburbs. "A kind of permanent proletariat was emerging in early nineteenth century cities—composed largely of day labourers and unskilled, propertyless workers, immigrants and blacks" (Mohl, 1972:936–937). Society was becoming more stratified and unequal with those at the bottom of the rung, the unskilled wage-laborers, becoming increasingly subject to business fluctuations, depressions, and unemployment which began to characterize this transitional period (Mohl, 1972).

Rochester, because of its location on two important waterways, became an increasingly important industrial and commercial center during the preindustrial era (Lanphear, 1990). As population grew, overcrowding resulted. This, in conjunction with the lack of clean water and a proper sewage system (Lanphear, 1990) must have resulted in a great deal of suffering from poverty and disease. The Monroe County Poorhouse was built at this time and probably housed unemployed laborers and skilled workers from Rochester. The inmates represent "the poorest members of the lowest socioeconomic class" who could not find employment and thus support themselves (Lanphear, 1990:38).

By the 1850s all major American cities had entered the industrial age (Betten, 1973). Because the individuals in the Hammon-Todd collection, known to be from the lowest socioeconomic stratum, were born in Cleveland between 1855-1913, they would have felt the negative effects of industrialization which "produced the most degraded urban environment the world had yet seen" (Mumford, quoted in Mohl, 1985:65–66). By the last half of the 19th century, American cities had become massive centers for industrial factories—the increasing number of European immigrants and rural migrants living in the city slums near the factories served as the primary workforce (Miller, 1973). As the American economy became increasingly dependent on fluctuating international trade, depressions hit regularly (major depressions occurred in 1873-1878, 1882-1886, and 1893-1897), resulting in severe unemployment and poverty (Mohl, 1985). As unemployment and poverty intensified, public attitudes toward the poor hardened and public assistance shrank significantly. Many who could not find work became vagrants—begging for food and living on the street (Betten, 1973).

Cleveland, like other Northeastern American cities, was more heavily urbanized than other parts of the United States throughout the industrial era. Population growth in Cleveland was so dramatic that it went from the 21st largest U.S. city in 1860 to the 5th largest by 1910. Most growth was the result of European immigration; by 1910 these immigrants and their American born children comprised over 70% of the population (Mohl, 1985).

In summary, the low prevalence of LEH observed in the colonial sample reflects the lack of social stratification and abundance of land and resources available to all inhibitants in early 18th century America. The increased prevalence of LEH observed in the Monroe County Poorhouse sample from Rochester reflects the beginning of the transition from an agricultural to an industrial-based society. Social classes were becoming stratified with unskilled laborers, usually European immigrants, living in an increasingly crowded urban environment. Finally, the high prevalence of LEH in the Hammon-Todd sample reflects the full-fledged industrialization of the American city in which large urban populations of unskilled workers, living in increasingly squalid conditions, were subject to highly unpredictable employment fluctuations.

Chronological distribution

The almost complete lack of LEH prior to 1.5 years of age can be interpreted within the context of four factors or combination of factors. Firstly, because of the large amount of slightly to moderately worn teeth in the sample (58%), the area of the tooth representing the first 0.5-year interval to the third 0.5-year interval was to some degree destroyed. Unfortunately, it is impossible to accurately determine the amount missing from each affected crown thus rendering it impossible to predict to what extent each of the three age categories are affected. This information would be required in order to eliminate those teeth missing the relevant

portion of the crown from new peak frequency calculations. As such, the extent to which attrition is responsible for the low frequency of LEH in the first three age categories remains unknown.

Secondly, other researchers (Blakey et al., 1992; Goodman and Armelagos, 1985a, b) have shown that the incisal third of the tooth crown is least susceptible to developing LEH compared to the remaining area of the crown. Again, to what extent this factor is responsible for the low frequency of LEH observed in the first three age categories is unknown.

Thirdly, the low prevalence of LEH prior to 1.5 years of age may indicate that the individuals in this sample experienced little biological stress as infants. This is consistent with the assertion that the colonial child's "first year of life was relatively tranquil (sic)" (Demos, 1970:134). As further support, others (e.g., McCusker and Menard, 1985; Norton, 1971) indicate that, in the general population, the incidence of infectious disease was low and poverty was virtually nonexistent in colonial North America. Alternatively, individuals in this sample may have experienced little biological stress as infants, not as a result of a favorable environment, in terms of disease, but because of their immunity against disease. Based on the mothers' past immunological experience, passive immunity may have been conferred, transplacentally, to their infants. Transplacentally derived antibodies may protect against tetanus, diphtheria, rubella, polio, mumps, *Escherichia coli,* meningococci, hepatitis B virus, group B streptococcus, salmonella, and measles (Hoshower, 1994). Protection is strongest at birth and diminishes over time depending on the amount originally transferred from the mother. The antibodies may be completely eliminated from the infants' circulatory system from 6 months to 1 year of age. Antibodies secreted in colostrum and breast milk also confer passive immunity to the newborn infant, but, because they remain in the digestive tract (and are not absorbed into the circulatory system), they provide protection against gastrointestinal diseases such as dysentery, cholera, streptococci, and salmonella (Hoshower, 1994).

In summary, even if there was a significant incidence of disease, the presence of maternal antibodies in both the blood stream and the gastrointestinal tract would protect the child from a number of illnesses during at least the first 6 months to 1 year of life.

Finally, the low frequency of LEH prior to 1.5 years of age may be related to infant mortality. Several sources indicate that infant mortality was high at the time when the majority of individuals in the sample were in their first few years of life (e.g., Caulfield, 1952; Demos, 1970; Greven, 1970). In fact, Cotton Mather, a Puritan Minister during the late 1600s and early 1700s, noted that infant mortality was "appalling" in the North American colonies (Beall and Shryock, 1954). As enamel hypoplasia is only recorded on individuals who survive biological stress, the possibility that high mortality rates would eliminate from the present sample those who experienced such stress cannot be discounted. This would suggest a strong filter in which individuals who survived the apparently vulnerable infant period experienced low mortality and morbidity later in life. This concurs with the analysis of prevalence of LEH in which the colonial sample had far fewer LEHs than the other two samples.

Attrition and decreased susceptibility of the incisal third of the crown are not mutually exclusive and both may be responsible, in conjunction with either of the "low morbidity" or the "high mortality" explanations, for the low frequency of LEH observed in the 0.0 to 1.5 year age categories. Unfortunately it is impossible to determine to what degree each of these factors, and indeed other unidentified factors, are responsible for the observed lack of enamel defects in this area of the tooth crown.

When all six tooth types are considered as a group, enamel hypoplasia peak frequencies are observed in age intervals ranging from 2.5 to 5.0 years of age. This pattern corresponds to the majority of other studies of LEH chronological distribution (e.g., Corruccini et al., 1985; Goodman et al., 1984, 1991; Lanphear, 1990) and is the same one that prompted Goodman and Armelagos (1985a,b) to investigate whether the frequency of hypoplasias by tooth type is influenced by time of crown development. Their research indicates that

on the anterior teeth the midsection (corresponding approximately to ages 2–4 years) contains 50% to 65% of the defects. There is no obvious reason why this intrinsically based differential susceptibility to the development of enamel defects does not apply to this sample as well. To date, no methodological tools have been developed to deal with this problem but, nonetheless, I believe the observed defects *do* represent biological stress. The question is, quite simply, how much stress is enough to produce a defect? It appears that much less biological stress is required to produce a defect in the middle one half of the crown compared with the incisal and gingival areas.

With this in mind it is pertinent to review the kinds of biological stress the colonial infant may have been exposed to following 2.5 years of age.

The maxillary central incisor and the mandibular central and lateral incisors record LEH peak frequencies beginning at 2.5 years of age while the remaining three tooth types record LEH peak frequencies at later ages. In studies of prehistoric archeological material weaning/post-weaning stress has been implicated as the cause of the increase of LEH at this time (e.g., Blakey and Armelagos, 1985; Goodman et al., 1984). Based on historical accounts, colonial North American infants were weaned at approximately 17 months or slightly later (Caulfield, 1952; Estes, 1979), resulting in an abrupt shift to a diet of sweetened maize gruel (Caulfield, 1952). More than likely there was considerable variability in age at which the weaning process began with the introduction of solid foods taking place over an extended period of time in conjunction with a reduction of breastfeeding. Regardless of the proposed variation, the weaning process, even if it occurred 6 months to 1 year later than Caulfield (1952) and Estes (1979) indicate, was probably too early to account for the majority of peak frequenices observed in the present sample. In fact, the pattern reported here supports Blakey and colleagues' (1994) research of LEH in enslaved African Americans in which they found that: "The highest frequencies of hypoplasia in these populations occur between 6 months and 3.75 years later than the expected age at weaning based on historical documentation" (Blakey et al., 1994:382).

Instead of weaning/post-weaning stress, the increase in frequency of LEH beginning at approximately 2.5 years of age may represent the combined effect of nutritional deficiences and exposure to disease. The majority of diseases common in colonial North America attacked young, nonimmune children. Older children and adults had already been exposed to the pathogen and had developed, as a result, appropriate antibodies, i.e., active immunity.

Malaria and smallpox were both highly contagious and characterized by high fever. As they were the most commonly occurring cause of childhood death in colonial North America (Duffy, 1953), it is likely that neither contributed significantly to the frequency of LEH observed in the present sample. Diphtheria and dysentery were the most commonly occurring childhood illnesses in frontier settlements (Duffy, 1953; Meindl and Swedlund, 1977). Both were characterized by high fever and the latter was rarely fatal (Estes, 1978). In addition, scarlet fever, measles, chicken pox, and mumps occurred frequently in nonimmune children and were rarely fatal (Caulfield, 1942; Duffy, 1953). As a consequence of contracting one or more diseases, children would develop active immunity and thereafter no longer be susceptible. Those individuals probably experienced good health for the remainder of their lives and may have had one or more hypoplastic defects as visible proof of earlier suffering.

Nutrition is linked with susceptibility to disease. A diet deficient in protein and/or calories decreases immunity, especially in young children. In addition, food intake is often reduced when a child is sick, thus compounding the situation (Frisancho, 1978). For this reason it is pertinent to explore both dietary habits and food availability of the colonists. Specific information pertaining to the dietary habits of children, by chronological age or as a general group, was not available, though some sources (Cummings, 1970; Estes, 1979) indicate that the dietary habits of children were the same as adults. Adult diet was examined to determine if nutritional factors could have affected the LEH observed in this sample.

The majority of sources indicate that the colonial diet was heavy, consisting mainly of salted pork and cornmeal (Cummings, 1970; Hawke, 1988; Shryock, 1962). Specifically, salted pork was the staple meat of the early colonial diet with fresh meat only being available from hunting or the slaughter of domestic animals in the summer (Cummings, 1970; McMahon, 1985).

Maize, adopted from the local Indians, was popular because it was a hardy crop, was easy to harvest, and had high yields (Hawke, 1988). In smaller homesteads, cornmeal stores were often depleted 1–2 months before mid-summer harvest. All frontier homesteads had a garden plot containing parsnips, carrots, onions and turnips, leafy greens, and medicinal herbs. Pumpkin, squash, and beans were planted in fields with the maize and in the autumn were collected along with root crops from the family garden, and stored in the cellar to be eaten over the winter (McMahon, 1985).

Fruit was not popular with the colonists but apples were harvested and stored on farms that had fruit trees. These were added to stews and helped to absorb some of the excess salt (McMahon, 1985).

In some areas, milk and cheese were abundant when pastures were green and even the smallest farms had at least one dairy cow. Cheese was a primary source of protein during the summer months but was not stored to be eaten throughout the winter. As there was no place for cattle to forage in the winter all dairying stopped in late autumn (McMahon, 1985).

Food shortages occurred in early spring when small to modest settlements shifted between stored and fresh food (McMahon, 1985). Except at this time, sources (e.g., Cummings, 1970) indicate that there was an abundant supply of provisions. During the winter months the diet was obviously lacking in essential nutrients such as those available from milk, fresh vegetables, and fruit. Nonetheless protein and calories were in abundant supply throughout most of the year and as such diet and food availability were likely not a factor in the genesis of LEH in the present sample.

CONCLUSIONS

The low prevalence of LEH observed in the colonial sample reflects the lack of social stratification and abundance of land and resources available to all inhabitants in early 18th century America. The increased prevalence of LEH observed in the Monroe County Poorhouse sample from Rochester reflects the beginning of the transition from an agricultural to an industrial-based society. Social classes were becoming stratified with unskilled laborers, usually European immigrants, living in an increasingly crowded urban environment. Finally, the high prevalence of LEH in the Hammon-Todd sample reflects the full-fledged industrialization of the American city in which large urban populations of unskilled workers, living in decrepit slums, were victims of a fluctuating employment market.

Several factors or combination of factors could account for the low frequency of LEH observed prior to 1.5 years of age. They include attrition, decreased susceptibility, low morbidity, and high mortality. Unfortunately it is not possible to determine to what extent each of these is responsible for the observed pattern. Weaning/post-weaning stress, so often implicated in past LEH studies as a major biological stressor, does not appear to be responsible for LEH peak frequencies observed in this sample. Historical sources indicate that weaning occurred at least 1 year earlier (at 17 months) than LEH peak frequencies observed on all six tooth types. Despite the fact that the middle half of the tooth crown has been shown to be more susceptible to LEH than other areas of the crown, the increase in frequency of LEH observed in this area must be, to some extent, the result of biological stress. At this age, children had not yet developed active immunity to diseases that were common in the region during colonial times. Their susceptibility would result in acquisition of one, if not several illnesses.

This study is unique in that it reports LEH frequency data for a skeletal sample representing the offspring of the first European settlers to the American colonies. Though historical data from this time period are not abundant, enough was available to provide a

context within which to interpret the enamel hypoplasia data. As the trend toward studying historical skeletal samples continues, interpretation of LEH data within the context of historical data will be increasingly employed as a means of understanding health and disease of individuals who lived during the time.

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